

Pattern Measurements of a Low-Sidelobe Horn Antenna

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The power pattern of a corrugated horn antenna designed for low sidelobes was measured to levels 90 dB below the main beam maximum in both the E- and H-planes. The measured patterns were found to be in good agreement with theoretical predictions.

I. Introduction

Requirements for antennas with high off-axis rejection are rapidly growing, and the study of such antennas is topical in current antenna technology. Applications requiring antennas with low-level sidelobes exist in earth-based and satellite communications, in radar systems, and in radio astronomy. The work reported here was motivated by a requirement for an antenna with very low sidelobes to measure properties of the cosmic microwave background radiation from a satellite (Ref. 1). The particular application calls for horn antennas of approximately 7-deg beamwidth, operating at discrete frequencies in the range 20 to 90 GHz, which have far-sidelobe levels lower than 85 dB below the main beam peak to adequately reject stray radiation from the earth. While antennas that meet this requirement have been designed, the sidelobe levels have not (to our knowledge) been measured to levels lower than 75 dB below the main peak (Refs. 2 through 4). As our requirements exceed the capabilities of

current state-of-the-art pattern measurement techniques, we undertook the task of extending these capabilities to meet our objectives.

We report the techniques and results of our antenna measurements here. The present work demonstrates that the sidelobes of horn antennas can be measured to significantly lower levels than has been achieved previously. The results should be of interest in both the measurement and further design of low-sidelobe antennas for other areas of application.

II. The Horn Antenna

A corrugated conical horn of the scalar feed horn antenna type was employed for the measurements. The horn, shown in Fig. 1, possesses a beamwidth of approximately 7 deg. It has been previously employed in an airborne experiment to measure the anisotropy of the cosmic background radiation

(Ref. 5). The design is based on pioneering studies by Kay (Ref. 6) and Potter (Ref. 7) of low-sidelobe antennas. Several authors, most notably Clarricoats and Saha (Ref. 8), have investigated the theoretical properties of this type of antenna. The significant features of this horn are its broad bandwidth, the 10-deg flare angle, and moderate groove spacing (two grooves/wavelength), which permit compact and easy construction. The design frequency of the horn is 33 GHz, although the pattern was not predicted to be significantly different at the present test frequency of 31.4 GHz. A transition section is employed to match the circular input port of the horn with rectangular waveguide.

III. The Measurement Technique

The strategy for the measurements was to use a conventional pattern measurement technique, while taking special precautions to eliminate the main sources of extraneous signals that could confuse the far-sidelobe measurements. The chief sources of background signal were anticipated to be radiation scattered into the main beam or near sidelobes from nearby objects, and radio frequency (RF) leakage into the receiver behind the horn due to imperfect connectors and junctions. Particular care was taken to obtain a clean and uncluttered test geometry, while the RF portion of the receiver was made extremely compact and easy to shield.

The measurement geometry illustrated in Fig. 2 was achieved by mounting a receiver with the test horn and transmitter on towers, illuminating the test horn on a horizontal path. The transmitter-receiver plane was thus removed 6 m from the ground to isolate the test system from nearby sources of reflection. The receiver tower was located at the edge of a mesa, the terrain beyond falling off sharply. The transmitter employed an identical low-sidelobe horn to further reduce potential reflection paths. The test horn was rotated in a horizontal plane by rotating the receiver tower on an azimuth bearing located near ground level. The axis of azimuth rotation passed through the point where the horn axis intersects its aperture, so that the incident signal was uniformly sampled as the azimuth was rotated to measure the sidelobes. The mount holding the receiver and test horn also rotated around the test horn axis, allowing the test horn polarization to be set at any chosen angle. The close spacing between transmitter and test horn (4 m) gave a sufficiently uniform illumination of the test horn while allowing for maximum signal strength.

Fig. 3 gives a schematic of the test circuit. A fixed-frequency Gunn oscillator supplied a continuous wave (CW) signal at the test frequency. A calibrated attenuator in the transmitter circuit allowed the transmitter power to be varied

from its maximum of 10 mW through a range of 50 dB. A series 1750 receiving system manufactured by Scientific Atlanta Corporation was employed and consists in essence of a narrow-band receiver that is phase-locked to the transmitter signal. The local oscillator employs a relatively low frequency signal (~ 2.6 GHz), the 12th harmonic of which is locked to the transmitter frequency. The advantage of this system is that the RF portion of the receiver is limited to the harmonic mixer and is very compact. For the measurements, the mixer was well wrapped with microwave-absorbing material in a small cylindrical volume behind the test horn. The received signal power was recorded on one axis of a two-axis plotter, the second axis of which was synchronized with the horn rotation angle.

IV. The Horn Pattern

After a series of measurements to guarantee proper alignment of the test system and receiver linearity, the pattern of the test horn was measured in both the H - and E -planes. The results are shown in Figs. 4 and 5, respectively. Receiver linearity was checked by obtaining a series of H -plane patterns with the transmitter reduced in 10-dB increments through a range of 50 dB, making use of the calibrated attenuator. The measured main beam maximum was found to decrease in corresponding 10-dB increments to within ± 1 dB in all cases. The measured patterns themselves were identical to within ± 2 dB down to approximately the 85-dB level shown in Fig. 4, where system noise becomes significant. Hence, the system linearity was demonstrated to be at least ± 2 dB over the full range 0 to 85 dB.

Receiver noise dominates the measurements below 90 dB. In the linearity measurements the noise level seen at angles beyond 100 deg in Fig. 4 was unchanged, while the patterns decreased in amplitude by up to 50 dB. If this noise were due in part to signal leakage, reflections, or receiver horn sidelobes, a relative decrease in this noise level would have been observed. As a further check, the receiver was wrapped with an additional layer of microwave-absorbing material, and the H -plane pattern was remeasured with no significant change observed. We conclude that the pattern measurements were limited by receiver noise alone.

The dashed curves in Figs. 4 and 5 show a theoretical calculation of the test horn pattern based on a computer program developed by Potter (Ref. 2). Although there are small deviations between the calculated and measured patterns, the overall agreement is excellent. The observed differences may be due to machining tolerances in the actual horn or to neglected contributions in the computations of the theoretical patterns.

IV. Conclusion

It is demonstrated that horn antenna patterns are measurable to levels less than 90 dB below the central peak with conventional range techniques. Further, existing theory for the performance of corrugated scalar feeds appears to give excellent predictions at these low-sidelobe levels. We believe that several factors contribute to the measurement success. First, the use of a relatively high frequency (31.4 GHz) maximizes the wavelength distances of unavoidable scattering objects in a given test environment, such as the ground and nearby buildings. In the present measurement, the receiver was located at the edge of a steep mesa so that the main power lobe of the transmitting antenna essentially disappeared into free space, with no chance for multipath reflections into the

receiver for the vast bulk of the radiated signal. The power in such reflections was further reduced by using a low-sidelobe horn for the transmitter, identical to that measured in the experiment. Finally, the receiver RF path was maintained at a minimum by employing a well-shielded harmonic mixer immediately adjacent to the test horn output port.

The level of sensitivity reached in these measurements was limited by receiver noise, with no evidence to indicate the presence of extraneous signals. The test apparatus used had a fixed short time constant for signal integration, which limited the receiver sensitivity. A straightforward improvement could be achieved by allowing for longer signal integrations and incorporating a switched-reference measurement scheme to enable the accurate determination of very low signal levels.

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References

1. J. C. Mather, "COBE-Explorer of the Primeval Explosion," *Astronaut. Aeronaut.*, pp. 60-66, Oct. 1978.
2. A. Ludwig, J. Hardy, and R. Norman, *Gain Calibration of a Horn Antenna Using Pattern Integration*. Technical Report 32-1572, Oct. 1972. Jet Propulsion Laboratory, Pasadena, California.
3. P. D. Potter, *A New Computer Program for the Design and Analysis of High Performance Conical Feed Horns*. Technical Report 32-1526, Vol. XIII, pp. 92-107, Feb. 1973. Jet Propulsion Laboratory, Pasadena, California.
4. H. P. Coleman, R. M. Brown, and B. D. Wright, "Paraboloidal Reflector Offset With a Corrugated Conical Horn," *IEEE Trans. Antennas Propagat.*, pp. 817-819, Nov. 1975.
5. G. F. Smoot, M. V. Gorenstein, and R. A. Muller, "Detection of Anisotropy in the Cosmic Blackbody Radiation," *Phys. Rev. Lett.*, Vol. 39, pp. 898-901, Oct. 1977.
6. A. F. Kay, *A Wide Flare Horn - A Novel Feed for Low Noise Broadband and High Aperture Efficiency Antennas*. Report 62-757, U.S. Air Force Cambridge Research Laboratory, Oct. 1962.
7. P. D. Potter, "A New Horn Antenna With Suppressed Sidelobes and Equal Beamwidths," *Microwave J.*, Vol. VI, No. 6, pp. 71-78, June 1963.
8. P. J. B. Clarricoats and P. K. Saha, "Propagation and Radiation Behavior of Corrugated Feeds: Part II - Corrugated-conical Horn Feed," *Proc. Inst. Elec. Eng.*, Vol. 118, pp. 1177-1186, Sept. 1971.

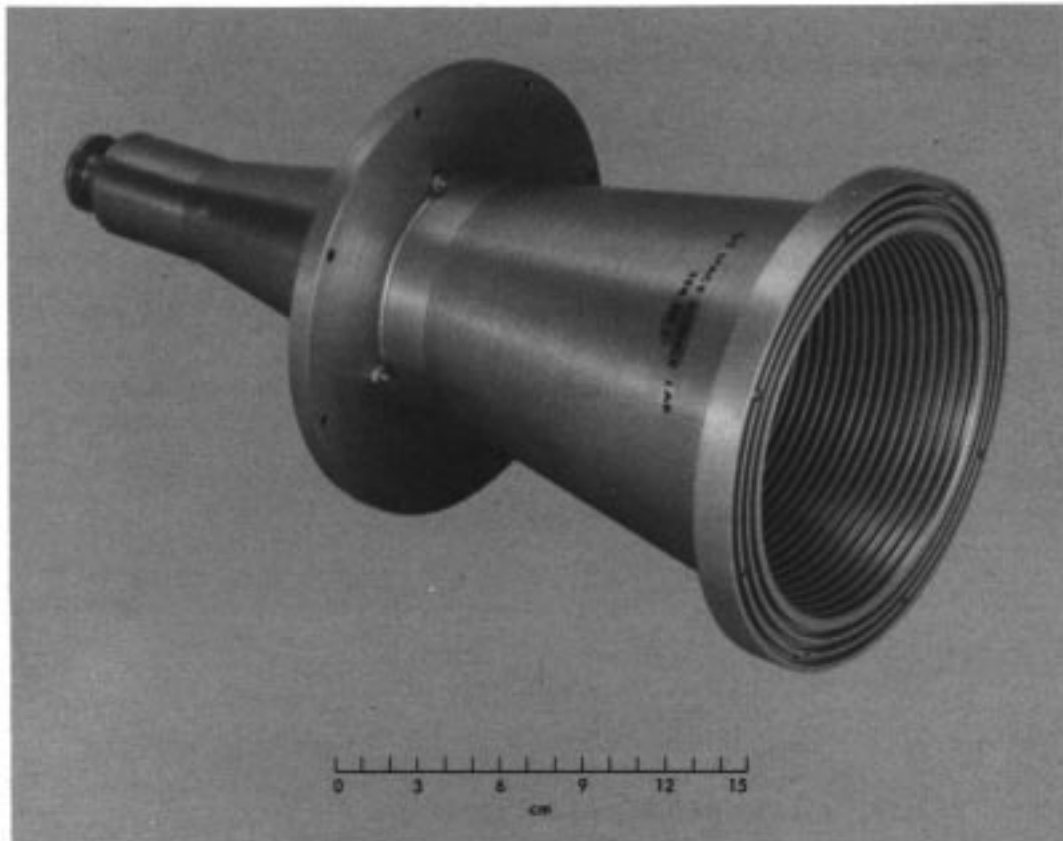


Fig. 1. Test horn—corrugated, conical scalar feed horn antenna. Flare angle is 10 deg, and groove spacing is approximately 0.5 wavelengths. Choke grooves on rim face are to suppress potential backlobe radiation.

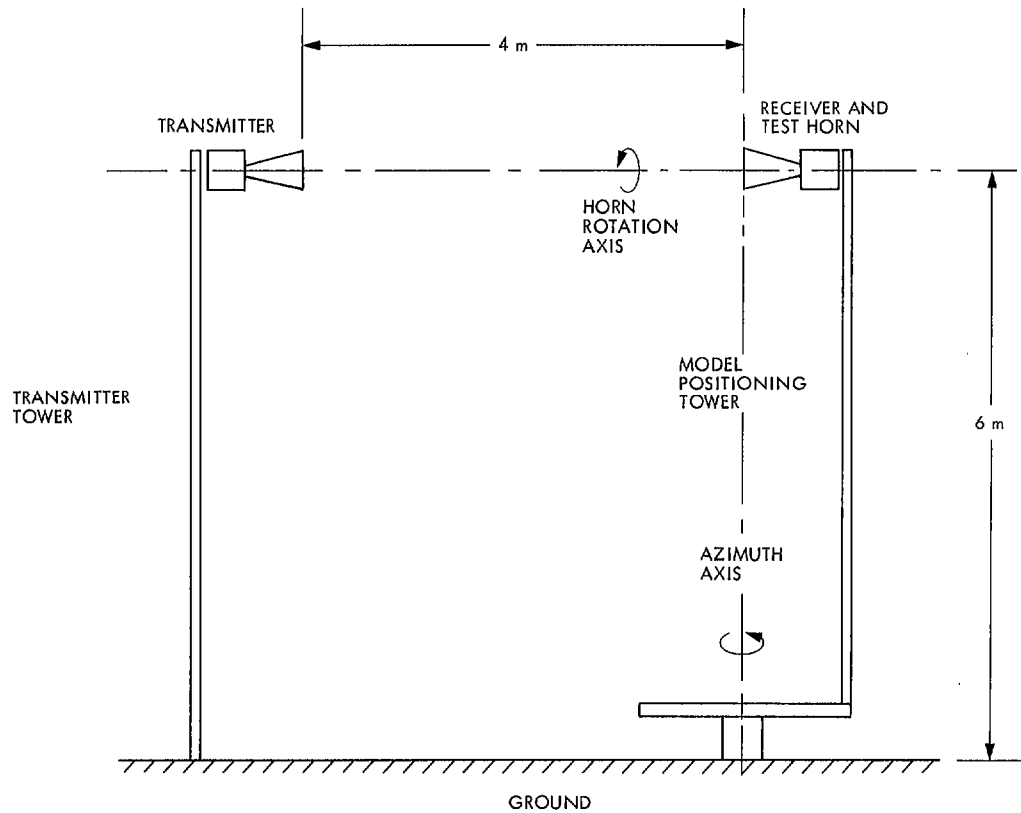


Fig. 2. Schematic of pattern measurement geometry

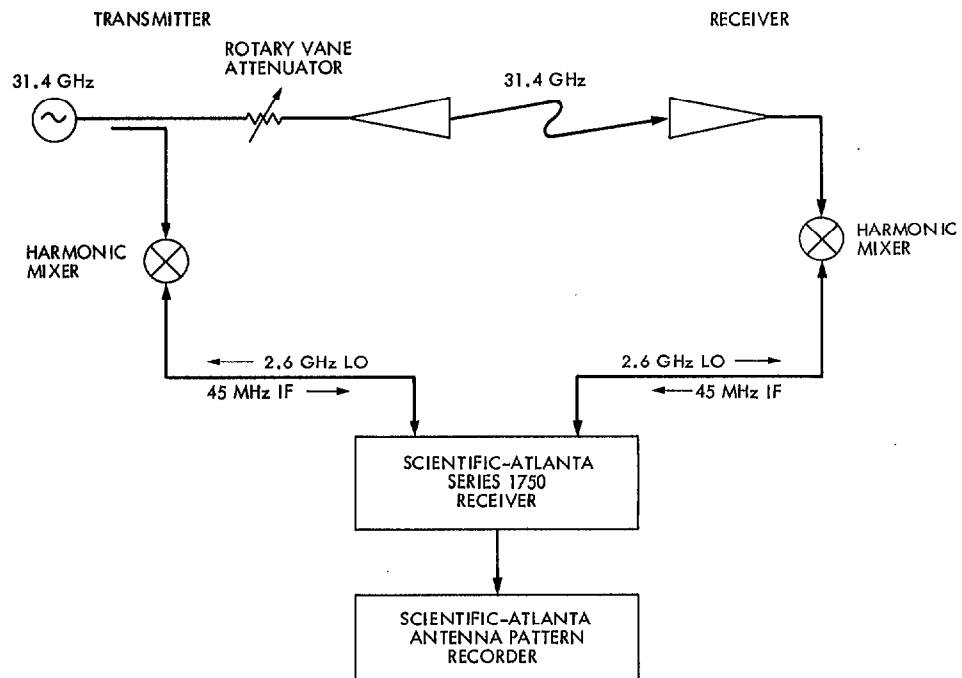


Fig. 3. Test circuit schematic

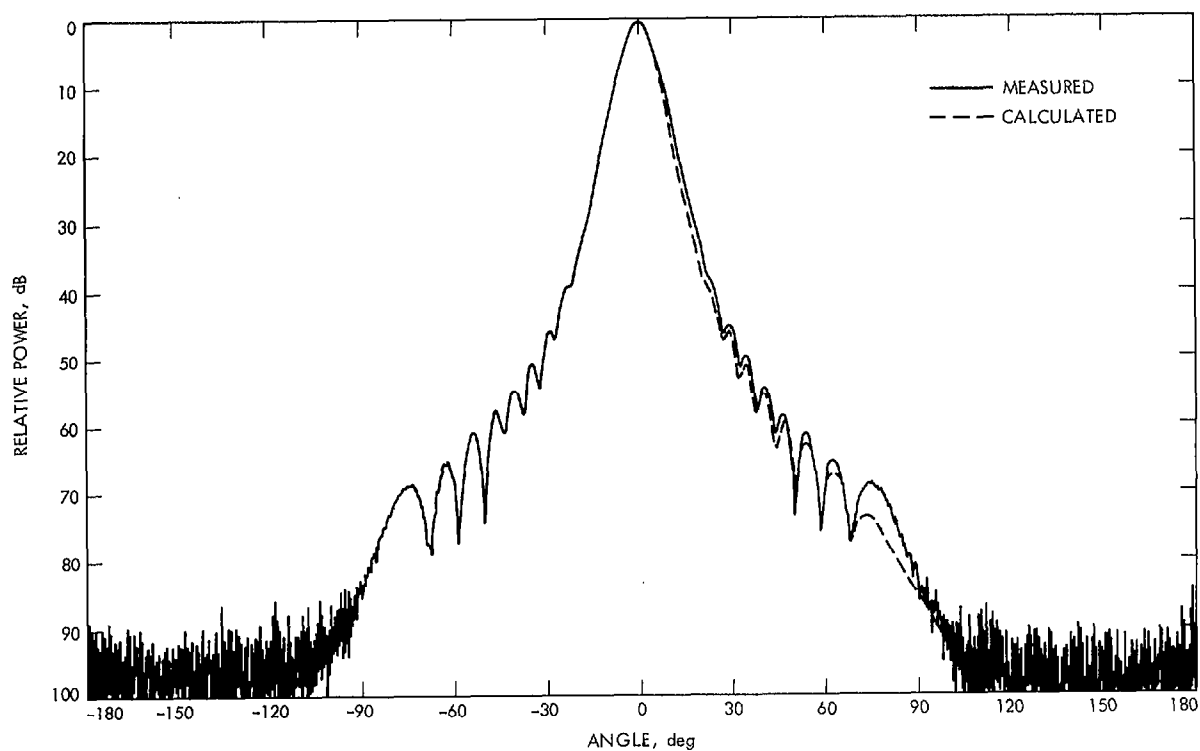


Fig. 4. *H*-plane radiation pattern of test horn. Receiver noise dominates below 90 dB.

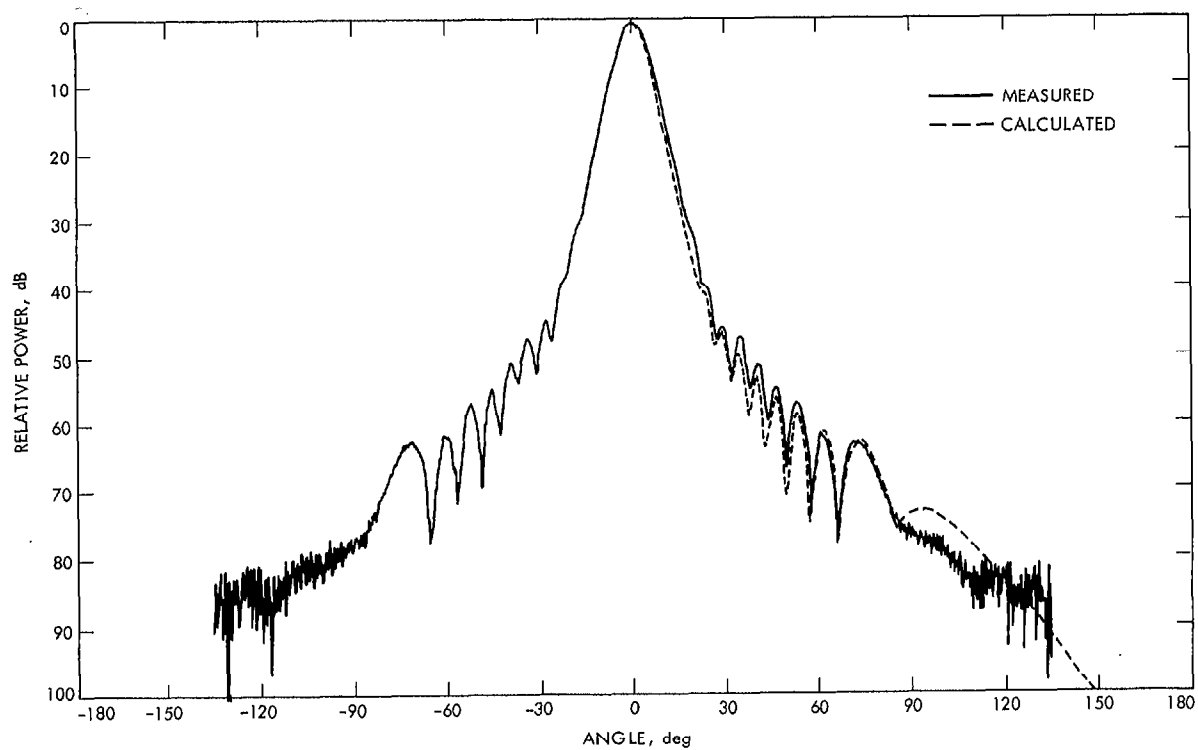


Fig. 5. *E*-plane radiation pattern of test horn